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**UNITED STATES PATENT APPLICATION**

of

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for

**INTERLEVEL DIELECTRIC STRUCTURE**

**AND METHOD OF FORMING SAME**

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5a1 This application is a divisional of application serial number 09/249,659, filed on February 12, 1999, which is a divisional application of serial number 08/677,514, filed on July 10, 1996, titled Interlevel Dielectrics and Methods for Forming the Same, both of which are incorporated herein by reference.

The present invention relates to the design and manufacture of interlevel dielectrics in the manufacture of semiconductor devices. More particularly, the present invention relates to the design and manufacture of interlevel dielectrics in the manufacture of semiconductor devices in which the dielectric constant of the interlevel dielectric is less than about 3.6.

The continuing trend in the semiconductor industry of squeezing more and more circuit devices into a given area has resulted in significant improvements in the performance of individual integrated circuits and of electronic devices that employ integrated circuits. In a typical integrated circuit, individual circuit elements or groups of elements are generally electrically connected together by a metallization process, in which layers of metal are deposited and patterned to form metal lines which complete the circuit as designed. Multiple metal layers are often employed. Metal lines within patterned metal layers are insulated by layers known as interlevel dielectrics. The interlevel dielectrics insulate the metal lines from any undesired electrical contact both with other metal lines, whether in the same or another metal layer, and with other circuit elements.

The capacitance between two conductive materials is also affected by the material as well as the distance between them. The ratio of the capacitance between two conductors with a given material between them to the capacitance of the same two conductors with

1 nothing (a vacuum) between them is known as the dielectric constant of the given material.  
2 Thus a material with a high dielectric constant placed between two conductors increases the  
3 capacitance between the two conductors.

4 The increasing density of integrated circuits has resulted in unneeded capacitance  
5 between metal lines in an integrated circuit due to metal line coupling capacitance. The  
6 unneeded capacitance slows circuit performance by causing too much buildup of charge  
7 where none is needed, thus slowing the buildup of charge at circuit elements where it is  
8 needed.

9 *sub 02* One way to decrease unneeded capacitance between metal lines in an integrated  
10 circuit is to decrease the dielectric constant of the material between them. Silicon dioxide,  
11 the material of choice for interlevel dielectrics, has a relatively high dielectric constant.  
12 Replacing silicon dioxide with a material having a lower dielectric constant would thus  
13 provide reduced capacitance. Useable materials having a low dielectric constant (e.g. less  
14 than about 3.6.) are generally much less stable than silicon dioxide and are thus unable to  
15 reliably protect the metal lines, and are ~~unable withstand further processing.~~

16 *sub 03* One way to gain some of the benefits of low dielectric constant materials is shown  
17 in Figure 1. Figure 1 is a partial cross section of a partially formed integrated circuit  
18 device. A substrate or lower layer 12 has a first dielectric layer 14 comprised of a traditional  
19 dielectric material such as silicon dioxide. Lines of conductive material 16, typically metal,  
20 overlie first dielectric layer 14. A material with a dielectric constant lower than that of  
21 silicon dioxide 18 is located in between lines of conductive material 16. Lines of conductive  
22 material 16 together with low dielectric constant dielectric material 18 are covered by a  
23 second dielectric layer 21 comprised of a traditional dielectric material such as silicon  
24 dioxide. Second dielectric layer 21 together with first dielectric layer 14 isolate low  
25 dielectric constant dielectric material 18 from other portions of the integrate circuit. Second  
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1 dielectric layer 21 allows further processing, including formation of contact holes for  
2 contacting lines of conductive material 16 such as contact hole 46, without exposing  
3 dielectric material 18 to processing agents.

4 While the structure shown in Figure 1 results in decreased capacitance between  
5 adjacent pairs of metal lines, further decrease is needed to allow increasing miniaturization  
6 and high speed operation of ever denser integrated circuits.

SUMMARY OF THE INVENTION

may In accordance with the present invention, an interlevel dielectric structure includes first and second dielectric layers between which are located lines of a conductive material with a dielectric material in spaces between the lines of conductive material, with the lower surface of the dielectric material extending lower than the lower surface of lines of conductive material adjacent thereto, and the upper surface of the dielectric material extending higher than the upper surface of lines conductive material adjacent thereto, thus reducing fringe and total capacitance between the lines of conductive material. The dielectric material, which has a dielectric constant of less than about 3.6, does not extend directly above the upper surface of the lines of conductive material, allowing formation of subsequent contacts down to the lines of conductive material without exposing the dielectric material to further processing.

A preferred method for forming the interlevel dielectric structure includes providing an additional layer on a conductive layer on a first dielectric layer, then patterning both the additional layer and the conductive layer with an over etch into but not through the first dielectric layer, to form conductive lines with spaces therebetween. A dielectric material is then deposited to fill the spaces and is then etched or chemically mechanically polished back to the additional layer on the conductive layer. The additional layer on the conductive layer is then optionally removed before a second dielectric layer is deposited over all.

Another preferred method for forming the interlevel dielectric structure includes providing a conductive layer on a first dielectric layer, then patterning the conductive layer with an over etch into but not through the first dielectric layer to form conductive lines with spaces therebetween. An additional layer is then deposited by a method providing poor step coverage. The additional layer is then optionally etched, and a dielectric material is then deposited in the spaces. The dielectric material is then etched or chemically mechanically

1 polished back to the additional layer. The additional layer is then optionally removed before  
2 a second dielectric layer is deposited over all.

3 Yet another preferred method for forming the interlevel dielectric structure includes  
4 providing a metal layer on a first dielectric layer, then patterning the metal layer with an over  
5 etch into but not through the first dielectric layer to form metal lines with spaces  
6 therebetween. A thin layer of silicon dioxide is then deposited by a method providing  
7 preferential deposition on the upper surfaces of the metal lines. The thin layer of silicon  
8 dioxide is then optionally etched, and a dielectric material is then deposited to fill the spaces  
9 and is then etched or chemically mechanically polished back. A second dielectric layer is  
10 then deposited over all.

11 The above briefly described methods allow reliable formation of a desired interlevel  
12 dielectric structure, which structure provides reduced total capacitance between adjacent  
13 conductive lines needed for further miniaturization of integrated circuits.

## BRIEF DESCRIPTION OF THE DRAWINGS

In order that the manner in which the above-recited and other advantages and objects of the invention are obtained may be more fully explained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments and applications thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments and applications of the invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

Figure 1 is a partial cross section of a partially formed integrated circuit device.

Figure 2 is a partial cross section of a partially formed integrated circuit device having a structure formed during the practice of a method of the present invention.

Figure 3 is a partial cross section of a partially formed integrated circuit device for use with a method of the present invention.

Figure 4 is a cross section of the structure shown in Figure 3 after further processing, and having a structure formed by a method of the present invention.

Figure 5 is a partial cross section of a partially formed integrated circuit device showing features formed during the practice of a method of the present invention.

Figure 6 is a partial cross section of a partially formed integrated circuit device depicting facet etching of a bread-loafed dielectric on metallization lines.

Figure 7 is a cross section of the structure shown in Figure 5 after further processing, and having a structure formed by a method of the present invention.

Figure 8 is a partial cross section of a partially formed integrated circuit device showing features formed during the practice of a method of the present invention.

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Figure 9 is a cross section of the structure shown in Figure 8 after further processing,  
having a structure formed by a method of the present invention.



The present invention introduces an interlevel dielectric structure having a dielectric material between conductive lines with a lower surface of the dielectric material below a lower surface of the conductive lines, and an upper surface of the dielectric material above an upper surface of the conductive lines. The present invention also provides various methods for constructing the inventive structure. Because silica glass is used extensively in this art as a dielectric, and its dielectric constant is about 3.8, we define the interlevel dielectric material as one having a dielectric constant below about 3.6, preferably below about 2.9, and most preferably below about 2.2.

A second dielectric layer 20 overlies lines of conductive material 16, with a lower surface 28 of second layer of dielectric material 20 being in contact with upper surfaces 26 of lines of conductive material 16.

One preferred method of forming a structure of the present invention includes providing a first dielectric layer 14 over the surface of a substrate of an underling layer 12,

Another preferred method of forming a structure of the present invention includes providing a first dielectric layer over a substrate or an underlying layer, then depositing and patterning a conductive layer over the first dielectric layer. During patterning of the conductive layer, the conductive layer is over etched such that the first dielectric layer is

1 etched partially with the same pattern. Next, an additional layer is deposited over the  
2 patterned metal layer by a deposition method having poor step coverage.

3 The results of the above steps are shown in Figure 5. First dielectric layer 14 has  
4 been formed on substrate or underlying layer 12, and a conductive layer has been deposited  
5 and patterned, leaving lines of conductive material 16. Additional layer 38 has been  
6 deposited by a deposition method having poor step coverage. This results in additional layer  
7 38 being formed substantially only on the upper surfaces of lines of conductive material 16  
8 as shown.

9 If additional layer 38 is comprised of a suitable dielectric material, the further  
10 process steps may proceed as before, with deposition and partial top-down removal of  
11 dielectric material 17 and deposition of second dielectric layer 21, resulting in the structure  
12 shown in Figure 7. The remaining portions of additional layer 38 are incorporated into the  
13 inventive structure as shown, so that the remaining portion of additional layer 38 in Figure  
14 5 together with second dielectric layer 21 in Figure 7, correspond to the depiction seen in  
15 Figure 2 as second dielectric layer 20.

16 Silicon dioxide is the currently preferred material for additional layer 38, with  
17 deposition by a silane and oxygen plasma enhanced chemical vapor deposition (PECVD)  
18 being the preferred poor step coverage deposition method.

19 Figure 6 illustrates an optional etch step that may be included immediately after  
20 deposition of additional layer 38 to remove lateral buildup of additional layer 38. The  
21 preferred etch is a facet etch, and is preferably performed in an argon or an argon-plus-  
22 fluorine based plasma. In a facet etch, additional layer 38 is etched slower at a top surface  
23 thereof than it is etched at a corner thereof which connects the top surface to a lateral surface  
24 thereof. The facet etch has the effect of removing substantially all of the lateral buildup  
25 portions of additional layer 38 and the removed portions redeposit in semi-triangular form  
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1 at the base of the lines of conductive material 16 and first dielectric layer 14 interface. A  
2 continuous but thin lateral layer of additional layer 38 also deposits down the sides of lines  
3 of conductive material 16. Further processing as above then results in a structure like that  
4 which is shown in Figure 4, with the remaining portions of layer of additional material 36  
5 corresponding to the remaining portions of additional layer 38. The redeposited fraction of  
6 additional material 38, however, remains thinly on the sides of lines of conductive material  
7 16 and first dielectric layer 14.

8 If additional layer 38 is not a dielectric, or is otherwise not suitable to remain in  
9 place in the inventive structure, then additional layer 38 is removed by an appropriate process  
10 immediately before the deposition of second dielectric layer 21. This alternative additional  
11 process step results in a structure that is like that shown in Figure 2.

12 In yet another presently preferred method for forming a structure of the present  
13 invention, a first dielectric layer is provided over a substrate or an underlying layer, then a  
14 metal layer is deposited and patterned to form metal lines over the first dielectric layer.  
15 During patterning of the metal layer, the metal layer is over etched such that the first  
16 dielectric layer is etched partially with the same pattern. A thin silicon dioxide layer is then  
17 deposited conformably over the metal lines by a deposition process that deposits  
18 preferentially on the upper surface of the metal lines.

19 The above process results generally in the structure shown in Figure 8. First  
20 dielectric layer 14 is formed on substrate 12. Metal lines in the preferred form of aluminum  
21 lines 40 have been formed on first dielectric layer 14, and first dielectric layer 14 has been  
22 over etched in the same pattern as aluminum lines 40. A titanium nitride film 42 from a  
23 photolithography process used to pattern aluminum lines 40 remains on the upper surface of  
24 aluminum lines 40. While not required, inclusion of titanium nitride film 42 is presently  
25 preferred.  
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1 The preferred deposition process for selectively depositing a thin silicon dioxide  
2 layer 44 is an ozone based TEOS process, which preferentially deposits on TiN over silicon  
3 dioxide. Preferably, silicon dioxide layer 44 will be deposited only on titanium nitride  
4 film 42 and not on the sidewall of aluminum lines 40 as shown in Figure 8.

5 After deposition of silicon dioxide layer 44, the process may continue as with the  
6 other above processes by deposition and partial removal of a dielectric material 17, followed  
7 by deposition of second dielectric layer 21, resulting in the structure shown in Figure 9.  
8 Silicon dioxide layer 44 is incorporated into the inventive structure as shown, so that silicon  
9 dioxide layer 44 together with second dielectric layer 21 correspond to the depiction seen in  
10 Figure 2 as second dielectric layer 20.

11 As an alternative process step, an etch such as a facet etch in an argon or an argon-  
12 plus-fluorine based plasma may be performed on silicon dioxide layer 44 after the deposition  
13 thereof.

14 The present invention may be embodied in other specific forms without departing  
15 from its spirit or essential characteristics. The described embodiments are to be considered  
16 in all respects only as illustrated and not restrictive. The scope of the invention is, therefore,  
17 indicated by the appended claims and their combination in whole or in part rather than by the  
18 foregoing description. All changes which come within the meaning and range of equivalency  
19 of the claims are to be embraced within their scope.

20 What is claimed and desired to be secured by United States Letters Patent is:  
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ATTORNEYS AT LAW  
1000 EAGLE GATE TOWER  
60 EAST SOUTH TEMPLE  
SALT LAKE CITY, UT 84111

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rule 5

1 11. A method of forming an interlevel dielectric comprising the steps of:  
2 providing a first dielectric layer over a surface of a substrate situated on a  
3 semiconductor wafer;  
4 depositing a conductive layer on said first dielectric layer;  
5 patterning said conductive layer by  
6 forming a mask layer on said conductive layer, and  
7 etching through said conductive layer and into said first dielectric  
8 layer, leaving a space between adjacent remaining portions of said conductive  
9 layer, said adjacent remaining portions of said conductive layer forming lines  
10 of conductive material each having an upper surface;  
11 depositing an additional layer on the upper surfaces of lines of conductive  
12 material and on said first dielectric layer;  
13 depositing a layer of dielectric material having a dielectric constant of less  
14 than about 3.6 to fill said space;  
15 removing said layer of dielectric material from the top thereof downward to  
16 at least to the level of the top of said additional layer; and  
17 depositing a second dielectric layer over all layers on said surface of said  
18 substrate.

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20 12. The method as defined in Claim 11, wherein depositing an additional layer  
21 comprises depositing a layer of silicon dioxide by silane and oxygen based plasma  
22 enhanced chemical vapor deposition.  
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13. The method as defined in Claim 11, further comprising, after depositing an additional layer and before depositing a layer of dielectric material, of etching said additional layer.
14. The method as defined in Claim 13, wherein said additional layer has a top surface extending to a lateral surface at a corner, and wherein said step of performing an etch on said additional layer etches the corner of the additional layer faster than the top surface of the additional layer.
15. The method as defined in Claim 13, wherein said additional layer comprises silicon dioxide and wherein said step of performing an etch on said additional layer etches in an argon or an argon-plus-fluorine based plasma.
16. The method as defined in Claim 11, wherein at least one of said first and second dielectric layers comprises silicon dioxide.
17. The method as defined in Claim 11, wherein said dielectric material comprises PTFE.
18. The method as defined in Claim 11, wherein said additional layer comprises silicon dioxide.
19. The method as defined in Claim 11, wherein said step of removing said layer of dielectric material comprises an etch back step.

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20. The method as defined in Claim 11, wherein said step of removing said layer of dielectric material comprises a chemical mechanical polishing step.
21. The method as defined in Claim 11, wherein said conductive material is selected from the group consisting of polysilicon, aluminum, and copper.
22. A method of forming an interlevel dielectric comprising the steps of:
- providing a first dielectric layer over a surface of a substrate situated on a semiconductor wafer;
  - depositing a metal layer on said first dielectric layer;
  - patterning said metal layer by
    - forming a mask layer on said metal layer, and
    - etching through said metal layer and into said first dielectric layer, leaving a space between adjacent remaining portions of said metal layer, said adjacent remaining portions of said metal layer forming metal lines each having an upper surface;
  - depositing a thin layer of silicon dioxide conformably over said metal lines and selectively on said upper surfaces of said metal lines;
  - depositing a layer of dielectric material having a dielectric constant of less than about 3.6 to fill said space;
  - removing said layer of dielectric material from the top thereof downward to at least to the level of the top of said additional layer; and
  - depositing a second dielectric layer over all layers on said surface of said substrate.

- 1 23. The method as defined in Claim 22, wherein said step of depositing a layer of  
2 silicon dioxide conformably over said metal lines and selectively on said upper  
3 surfaces of said metal lines comprises an ozone-based TEOS deposition.  
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5 24. The method as defined in Claim 22, wherein said metal lines comprise aluminum  
6 with a titanium nitride film on said upper surface of said metal lines.  
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8 25. The method as defined in Claim 22, further comprising, after depositing a layer of  
9 silicon dioxide conformably over said metal lines and before depositing a layer of  
10 dielectric material, of etching said additional layer.  
11  
12 26. The method as defined in Claim 25, wherein said additional layer has a top surface  
13 extending to a lateral surface at a corner, and wherein said step of performing an  
14 etch on said additional layer etches the corner of the additional layer faster than the  
15 top surface of the additional layer.  
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17 27. The method as defined in Claim 26, wherein said additional layer comprises silicon  
18 dioxide and wherein said step of performing an etch on said additional layer etches  
19 in an argon or an argon-plus-fluorine based plasma.  
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21 28. The method as defined in Claim 22, wherein at least one of said first and second  
22 dielectric layers comprises silicon dioxide.  
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24 29. The method as defined in Claim 22, wherein said dielectric material comprises  
25 PTFE.  
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30. The method as defined in Claim 22, wherein said additional layer comprises silicon dioxide.
31. The method as defined in Claim 22, wherein said step of removing said layer of dielectric material comprises an etch back step.
32. The method as defined in Claim 22, wherein said step of removing said layer of dielectric material comprises a chemical mechanical polishing step.
33. The method as defined in Claim 22, wherein said metal layer comprises at least one of aluminum or copper.
34. A method of forming an interlevel dielectric comprising:
  - providing a first dielectric layer over a surface of a substrate;
  - forming a conductive layer on said first dielectric layer;
  - forming an additional layer on said conductive layer;
  - forming lines of conductive material having spaces therebetween from the conductive layer;
  - filling the spaces between the lines of conductive material with dielectric material having a dielectric constant of less than about 3.6;
  - forming a second dielectric layer on the additional layer.

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A method of forming an interlevel dielectric comprising:

providing a first dielectric layer over a surface of a substrate;

forming a conductive layer on said first dielectric layer;

forming an additional layer on said conductive layer;

etching through said additional layer and said conductive layer and into said first dielectric layer, leaving a space between adjacent remaining portions of said conductive layer, said adjacent remaining portions of said conductive layer forming lines of conductive material;

filling the spaces between adjacent remaining portions of said conductive layer with dielectric material having a dielectric constant of less than about 3.6;

forming a second dielectric layer on the additional layer.

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